SPECIFICATION (Ref;FEM-1624)

TITLE

GUIDE PLATE, SURFACE LIGHT SOURCE DEVICE OF SIDE LIGHT TYPE AND LIQUID CRYSTAL DISPLAY

BACKGROUND

1.FIELD OF INVENTION

The present invention relates to a guide plate, surface light source device of side light type and liquid crystal display, in particular, to an improved guide plate, surface light source device of side light type employing the improved guide plate and liquid crystal display employing the surface light source device for illuminating a liquid crystal display panel.

2.RELATED ART

Known liquid crystal displays belong either to a kind employing a transmission-type liquid crystal display panel or to another kind employing a reflection-type liquid crystal display panel. In general, the former hardly permits ambient light to be used for image formation, leading to employment of surface light source devices such as those of side light type for back-lighting of the transmission-type liquid crystal display panel.

On the contrary, the latter enables ambient light to be used for image formation, leading to saving of electric power consumption. However, any illuminating device for illumination a reflection-type liquid crystal display panel is required under conditions being short of ambient light, for example, at night. So-called surface light source device of side light type are suitable for such a use. That is due to side-by-side arrangement such that a primary light source is disposed beside a guide plate to bring only a slight increasing of thickness to a liquid crystal display.

Illumination light is supplied to a reflection-type liquid crystal display panel usually from the front side in the same way as ambient light. It is, however, known to have a reflection-type liquid crystal display panel function temporally as a transmission-type

liquid crystal display panel. That case allows back-lighting of the liquid crystal display panel to be employed.

Liquid crystal displays employing front-lighting arrangement are known as disclosed in Japanese Patent Laid-Open Heisei (Tokkai-Hei) 10-142601. Fig.12 is a cross section view to illustrate an out-lined structure of the disclosed display.

Referring to Fig.12, a surface light source device of side light type 1 is disposed for front-lighting of s reflection-type liquid crystal display panel 2. The surface light source device 1 comprises a guide plate 3 and a primary light source 4 disposed beside the guide plate. The guide plate 3 is arranged at the display screen side of the reflection-type liquid crystal display panel 2. The primary light source 4 is composed of, for instance, a fluorescent lamp 5 and a reflector 6 partially enclosing the lamp. The guide plate 3 has an end face to provide an incidence end face 3A which is supplied with illumination light L from the fluorescent lamp 5 through an opening of the reflector 6.

The guide plate 3 is a plate-like member made of a transparent material such as acrylic resin (PMMA resin), which may be produced through injection mold technique. The guide plate 3 has major faces to provide an inner face 3B and an outer face 3C which is opposite with the inner face. The inner face 3B is facing to the liquid crystal display panel 2.

Illumination light L is introduced into the guide plate 3 and propagates within the guide plate so as to distancing the incidence end face 3A with repeated inside reflections at the inner face 3B and outer face 3C. In this process, emission occurs little by little from the inner face 3B and outer face 3C. Emission from the inner face 3B is supplied to the liquid crystal display panel 2, contributing to image formation according to well-known manners.

The inner face 3B is provided with a great number of ridges 3E to promote emission from the inner face 3B. It is noted that " ridge " is defined as " projection extending with a small width " . The ridges 3E extend in parallel with the incidence end face 3A (i.e. vertical to the drawing paper face).

As shown in a partial enlarged illustration indicate with reference symbol A, each ridge 3E has a pair of steep flank faces (side faces) 3F, which are angled almost vertical

to the inner face 3B, and a top face 3G which is angled almost parallel to the inner face 3B. Some of illumination light L which has entered into individual ridges 3E is emitted from the flank faces 3F or top face 3G. Needless to say, refraction occurs at every emission according to Snell's Law.

Thus emitted light impinges directly or indirectly onto the liquid crystal display panel 2. In other words, the inner face 3B provides a " emission function face " for the liquid crystal display panel 2 and the emission function face outputs light which is inputted to the liquid crystal display panel 2. As for ambient light, it is introduced into the guide plate 3 through the outer face 3C, then being inputted to the liquid crystal display panel 2 through the emission function face 3B.

Such light (illumination light or ambient light) inputted to the liquid crystal display panel 2 is modified, being emitted from the outer face 3C to contribute display operation after transmitting through the guide plate 3.

However, the above-described prior arts are subject to serious problem. That is, many ridges 3E are conspicuous on viewing the guide plate 3 from above the outer face 3C, thereby inevitably reducing illumination quality and accordingly giving reduced display quality to a liquid crystal display.

It is needless to say that such conspicuousness could be eliminated by removing the ridges 3E to make the inner face 3B flat. However, such a flat inner face would not work enough as an emission function face when the fluorescent lamp 5 is lightened. That is due to a well-known fact that illumination light introduced sideways into the guide plate 3 is hardly able to escape through such a flat inner face.

According to another technique which seems to be applicable, the problem is solved by giving a much reduced size (in particular, width) to the ridges 3E. However, such size reduction involves falling in emission function, leading to difficulty in providing bright illumination and display.

OBJECT AND SUMMARY OF INVENTION

The present invention has been proposed under the above-described background. An object of the present invention is to improve the above prior art guide plate to

provide a guide plate provided with ridges which are able to get free from conspicuousness without deteriorating emission function. And another object of the present invention is to provide a surface light source device of side light type which employs the improved guide plate to give bright and high quality illumination output.

Still another object of the present invention is to provide a liquid crystal display which employs the improved surface light source device of side light type for lighting, in particular, for front-lighting of a liquid crystal display panel to realize bright and high quality display.

In the first place, the present invention is applied to a guide plate comprising an incidence end face to introduce illumination light and an emission function face provided with function to emit illumination light. The emission function face is provided with a great number of ridges each of which has a first flank face directed to the incidence end face and a second flank face opposite with the first flank face.

And, according to a basic and important feature of the present invention, each of the ridges extends in a direction which is inclined at an angle falling within a predetermined angle range with respect to the incidence end face. The angle range is preferably from 5 degrees to 45 degrees, in particular, from 15 degrees to 30 degrees.

The ridges extending obliquely work on light approaching each of them from directions of the incidence end face as they have enlarged width in comparison with conventional ridges extending in parallel with the incidence end face. Accordingly, if size of each ridge is reduced, less reduction in emission function will be caused as compared with prior arts. As described previously, the smaller size of each ridge is, it is the less conspicuous. After all, the present invention enables scarcely conspicuous ridges (small size ridges) to be employed while the ridges bring less reduced emission function.

Preferably, in the first and second flank faces, at least the latter is inclined so that distance from the incidence end face increases according to getting closer to each ridge top portion. It is more preferable that both of the first and second flank faces are inclined so that distance from the incidence end face increases according to getting closer to each ridge top portion.

Such embodiments help illumination light which has entered into each ridge to

undergo inside–reflection at the second flank face. As a result, directivity of emission from the emission function face is improved. In other words, emission from the emission function face is made be apt to be directed around frontward with respect to the emission function face.

Each ridge projects from a " general plane " of the emission face. Accordingly, the first and second flank faces connect with the emission function face at a pair of foot portions for each ridge. It is noted that " general plane (of an emission face) " is defined as a plane which represents an emission face and intersects with an incidence end face to provide one edge of the incidence end face.

According to a preferable embodiment employing a featured foot portions, the second foot portion provides a stepwise difference such that thickness of the guide plate is greater at the second foot portion as compared with at the first foot portion.

Such a stepwise difference between the foot portions, propagation directions of illumination light which is able to enter into each ridge is limited so as to have a large inside–incidence angle with respect to the second flank face. As a result, emission is made apt to be preferentially caused roughly frontward with respect to the emission function face.

The present invention is applied to a surface light source device of side light type which comprises a guide plate having an incidence end face to introduce illumination light and an emission function face provided with function to emit illumination light, and which further comprises a primary light source disposed beside the guide plate to supply illumination light. The surface light source device employs the guide plate to which improvements is applied in various manners as above, thereby enabling bright and high–quality illumination output to be realized.

The present invention is further applied to a liquid crystal display which employs the above improved surface light source device of side light type for illumination a liquid crystal display panel to realize bright and high–quality display. In particular, it is preferable to adopt the above improved surface light source device of side light type in a front–lighting]arrangement for the liquid crystal display panel.

The above–described and the other features will be understood more in details

through description below with referring to the accompanied drawings. It is noted that the drawings include illustrations with some exaggeration in size or shape for the sake of easy understanding.

BRIEF DESCRIPTION OF DRAWINGS

Fig.1 is an exploded perspective view from the bottom of a liquid crystal display of a first embodiment in accordance with the present invention;

Fig.2 is a cross section view along line B−B in Fig.1;

Fig.3 is a cross section view illustrating light paths of ambient light in a case where ridges have flank faces approximately vertical to a general face of an emission function face;

Fig.4 is a cross section view illustrating light paths of ambient light, in a manner similar to Fig.3, in a case where ridges have flank faces obliquely (i.e. not vertical) to a general face of an emission function face;

Figs.5a, 5b and 5c are plan views illustrating operations of obliquely extending ridges, Fig.5a showing prior art, Figs.5b and 5c showing cases in accordance with the present invention;

Fig.6 is an exploded perspective view of a liquid crystal display of a second embodiment in accordance with the present invention;

Fig.7 is a cross section view along line G−G;

Fig.8 is a cross section view illustrating light paths of illumination light in a case where ridges accompany no stepwise difference;

Fig.9 is a cross section view illustrating light paths of illumination light in a case of ridges shown in Fig.7;

Fig.10 is an exploded perspective view of a liquid crystal display of a third embodiment in accordance with the present invention;

Fig.11 is an exploded perspective view of a liquid crystal display of a forth embodiment in accordance with the present invention;and,

Fig.12 is a cross section view of a liquid crystal display to which a conventional surface light source device of side light type is applied in a front−lighting arrangement.

EMBODIMENTS

<1> First Embodiment

Referring to Figs.1 and 2, a liquid crystal display 10 comprises a liquid crystal display panel 11 of reflection type and a surface light source device of side light type 12. The surface light source device 12 is disposed at the outside of the liquid crystal display panel 11 (i.e. at display screen's side or viewing side) for front-lighting.

The liquid crystal display panel 11 is structured and operates in a well-known manner. That is, the liquid crystal display panel 11 comprises a reflection plate 11A, glass substrate 11B, liquid crystal layer 11C, glass substrate 11D and polarization plate PL which are laminatedly arranged. The glass substrate 11B and glass substrate 11D are provided with matrix-like transparent electrodes (not shown), respectively. The transparent electrodes are driven by a driving circuit (not shown) to control polarization state of light which transmits through the liquid crystal layer 11C. Accordingly, output light of the liquid crystal display panel forms an image.

The surface light source device 12 comprises a guide plate 13 and primary light source 14. The guide plate 13 has an end face to provide an incidence end face through which the plate is supplied with illumination light from the primary light source 14. The primary light source 14 is composed of, for example, a fluorescent lamp 15 and a reflector 16 backing the lamp. Illumination light is directed to the incidence end face 13A through an opening of the reflector 16. The guide plate 13 introduces illumination light forming a beam flux which has some angular extent. For the sake of explanation, the flux is represented by " illumination light L " as shown in Fig.2.

The guide plate 13 is a plate-like member made of a transparent material such as acrylic resin ()PMMA resin), which can be produced through application of injection mold techniques. The guide plate 13 has major faces to provide an inner face 13B and an outer face 13C which is opposite with the inner face. The inner face 13B is facing and close to the liquid crystal display panel 11.

The inner face 13B has a great number of ridges to provide an emission function face which is capable of promoting emission. It is noted again that " ridge " is defined

as “ projection extending with a small width ” .

According to the most important feature of the present invention, the ridges 13E are substantially not parallel with respect to the incidence end face 13A, being inclined at a certain inclination angle α . Inclination angle α is determined according to design, preferably falling in a range from 5 to 45 degrees, in particular, from 15 to 30 degrees.

Such inclination arrangement increases illumination light which approaches obliquely each ridge in comparison with parallel arrangement of prior arts. This is further explained with reference to Figs.5a to 5c.

In Fig.5a (prior art), each ridge 13E has effective width W that is equal to actual width (i.e. distance vertically traversing each ridge) WD. It is noted that “ effective width W ” is “ effective ” width of each ridge 13E as viewed from the standpoint of light which is supplied from the lamp 15. In general, there is a relation, $W=WD/\cos\alpha$.

On the contrary, ridges 13 E obliquely arranged as shown in Figs.5b and 5c function so that each of them has effective width W that is greater than actual width WD. In other words, if such ridges as having WD smaller as compared with prior arts are employed, effective width W can be maintained. It is needless to say that ridges of small-size are hardly conspicuous and accordingly they prevent illumination quality of the surface light source device 12 and display quality of the liquid crystal display 13 from being deteriorated.

From another standpoint, the obliquely arranged ridges 13E reduces probability of appearing Moire fringes which could be brought in connection with other periodically arranged elements such as transparent electrodes. This prevents also illumination quality or display quality from being deteriorated. Technical meaning of the above numerical range of angle α is as follows.

First, if angle α is smaller than 5 degrees, the above described effect is hardly expected in practice. If angle α exceeds 15 degrees, the above described effect becomes quite tangible. However, if angle α is too great, for instance, exceeding 45 degrees, inside incidence angles in the ridges become large although effective width W becomes very great, with the result that emission efficiency falls and light supply direction to the liquid crystal display panel 11 tends to be much inclined. This tendency

become tangible little by little if angle α exceeds 30 degrees. Taking account of this, a practical range of angle α is from 5 to 42 degrees and, in particular, angle α preferably falls within a range 15 to 30 degrees.

The ridges 13E employed in the present embodiment are shaped so that the following conditions are satisfied (cf: partially enlarged illustration D in Fig.2).

(1)Every ridge 13E has generally one three-dimensional shape.

(2)Extent of "cross section in parallel with an outer face 13C" is getting smaller from a foot portion toward a top portion for each ridge.

(3)First and second flank faces 13EA and 13EB are inclined so that distance from the incidence end face 13A is getting greater from a foot portion toward a top portion for each ridge. This inclination is represented by angles a and b of the flank faces 13EB, 13EA with respect to a general plane of the emission face (the inner face 13B in the present embodiment). Accordingly, there is a relation, a <90 degrees and b >90 degrees.

This general plane and the incidence end face 13A provide an intersection which is one edge (a lower edge in Fig.2) of the incidence end face 13A. Thus each ridge inclined as a whole so that distance from the incidence end face 13A is getting greater from a foot portion toward a top portion.

On lighting of the fluorescent lamp 15, illumination light L is introduced into the guide plate 13 and then propagates within the guide plate 13 so as to be getting far from the incidence end face 13A with repeated inside-reflections at the inner and outer faces 13B and 13C.

Through this process, much of illumination light L get opportunity to enter into any of the ridges 13E. In general, entering into a ridge 13E succeeds to an inside-reflection at the outer face 13C. Therefore, as shown in partially enlarged illustration E, light which enters into a ridge 13E has an oblique directivity that is related to critical angle $\theta 1$ (see dotted line). For example, critical angle $\theta 1$ is 42.39 degrees if the guide plate 13 is made of acrylic resin (refractive index:1.49) which is a typical material.

Accordingly, inside-reflections at the outer face 13C are mostly total reflections. As a result, light which enters into a ridge 13E has entering angles greater than critical

angle θ 1. And the entering angles do not exceed 90 degrees because the entering light is a part of inside propagation light.

It is noted that " entering angle " is expressed with reference to a normal plane with respect to a general plane of the emission function face (the inner face 13B) in the same manner as in the case of critical angle θ 1.

Illumination light which has entered into each ridge 13E is subject to inside-incidence to the second flank face 13EB. Incidence angle at this inside-incidence is fairly large due to the aforesaid condition (3). As a result, inside-incidence light is mostly inner-reflected by the flank face 13EB and followed by inside-incidence to a top face 13G.

Incidence angle at this inside-incidence is small, in other words, nearly vertical incidence. Therefore, emission through the top face 13G occurs easily (see partially enlarged illustration D). This emission has directivity which is facing to the liquid crystal display panel 11 almost at the right angle as shown in partially enlarged illustration F.

If the second flank face 3F is steep vertically (without inclination) as shown in partially enlarged illustration A in Fig.12, emission through the flank face 3F increases, with the result the liquid crystal display panel 11 is supplied with light from greatly inclined directions (see beam M and its path in Fig.12). The present embodiment avoid this and realizes promoted light supply from around a frontal direction (approximately, within 30 degrees with respect to the frontal direction).

In general, directivity of light entering into a ridge 13E varies to some extent depending on conditions such as thickness of the guide plate 13 or relation between the incidence end face 13A and the primary light source 14. Accordingly, inclination angle a of the second flank face 13EB is preferably set at a designed angle within a range, 45 degrees $< a <$ 90 degrees, in particular, 60 degrees $< a <$ 80 degrees under consideration of the conditions. This angle setting is designed so that entering light is well subject to total reflection at the flank face 13EB and impinges to the liquid crystal display panel 11 at a small incidence angle through the top face 13G.

On the other hand, for inclination angle b of the first flank face 13EA, care is taken so that inner incident light to the flank face 13B is not shielded. Care is also taken

not to make " mold release " difficult in molding of the guide plate 13. Concretely saying, angle b falls preferably within a range from " 90 degrees + critical angle θ 1 " to " 180 degrees − angle a " .

Height of reach ridge 13E h is preferably about 20 μ m. And ration of h to width (actual width) WD falls preferably within a range from 0.5 to 1.0. It is noted that indication of W in Fig.2 is " effective width " .

In the present embodiment, formation interval of the ridges 13E is getting smaller according to distance from the incidence end face 13A. This employed in order to prevent inner propagation light, which is getting weak according to distance from the incidence end face 13A, from bringing short of light supply to the liquid crystal display panel 11 according to the aforesaid distance. In other words, intended is uniformalizing of output light intensity distribution of the surface light source device 11.

The present embodiment employs a front−lighting arrangement. Accordingly, it is needless to say that the liquid crystal display 10 is capable of performing display operations, if put under plenty of ambient light, without lighting the fluorescent lamp 15. In general, ambient light can be introduced into the guide plate 13 through the outer face 13C regardless of on/off state of the fluorescent lamp 15.

Principle on the basis of which ambient light contributes to display operation is generally the same as that of prior arts. Ambient light is supplied to the liquid crystal display panel 11 from the inner face 13B (including the ridges 13E) of the guide plate 13 to contribute to display operation according to a well known principle. That is, ambient light takes a route such as ambiance → guide plate 13 → polarizer PL → glass substrate 11D → liquid crystal layer 11C → glass substrate 11B → reflection plate 11A → glass substrate 11B → liquid crystal layer 11C glass substrate 11D → polarizer PL → guide plate 13 → ambiance.

As well known, quantity of light that is finally outputted to ambiance after travelling such a go−and−come−back route is controlled depending on voltage applied to matrix−like transparent electrodes (not shown) formed on the substrates 11B and 11C. The output light of the liquid crystal display panel 11 gives image formation resultantly.

However, seeing details of the present embodiment, it has a feature regarding

behavior of ambient light. That is, the ridges 13E can avoid from looking whitish and hazy since the ridges 13E are formed so as to project obliquely. This is explained below with reference to Figs.3 and 4.

Fig.3 shows light paths of oblique ambient light LR in a case where ridges 3E of vertically projecting type are employed while Fig.4 shows light paths of oblique ambient light LR in a case of the present embodiment employing ridges 13E of obliquely projecting type. As illustrated in Figs.3 and 4, oblique ambient light LR is refracted so as to approach a direction of guide plate thickness at entering into the guide plates.

As a result, in both cases of Figs.3 and 4, oblique ambient light LR positively tends to be subject to inner impinging onto the flank face 13F or 13EB at an angle greater than the critical angle. Ambient light totally reflected at the flank face 3F ~~is~~ or 13EB subject to inner impinging onto the top face 3G or 13G.

It is important that inside-incidence angle to the top face 3G in Fig.3 is greater as compared with inside-incidence angle to the top face 13G in Fig.4. Accordingly, the former involves not a little light which is emitted to ambiance after undergoing total reflection at another flank face 3F again and penetrating the guide plate 13 as shown in Fig.3. Needless to say, such light is not desirable because it gives whitish and hazy background to the display screen without contribution to display operation.

On the contrary, the latter involves plenty of light which outgoes to be supplied to the liquid crystal display panel 11 (see Fig.2) because inside-incidence to the top face 13G occurs at nearly vertical angles as shown in Fig.4. Ambient light LR' which is subject to inside-incidence to the inner face 13B so as to avoid the ridges 13EB outgoes toward the liquid crystal display panel 11 too as illustrated. Therefore, a little light is emitted to ambiance without contribution to display, hardly producing whitish and hazy background.

<2> Second Embodiment

Figs.6 and 7 give an exploded perspective view of a liquid crystal display 20 according to a second embodiment. Fig.9 illustrates light paths of illumination light in the present embodiment. Hereafter, members common to the first embodiment are

referenced commonly with simplified description on them.

Referring in the first place to Figs.6 and 7, the liquid crystal display 20 comprises a reflection– type liquid crystal display panel 11 and a surface light source device of side light type 22. The surface light source device 22 is disposed at the outside (i.e. at the screen side or viewing side) of the liquid crystal display panel 11 for front– lighting of the panel. The liquid crystal display panel 11 is structured and works as described in the description of the first embodiment.

The surface light source device 22 comprises a guide plate 23 and a primary light source 14. The guide plate 23 has an end face to provide an incidence end face 23A through which the guide plate 23 is supplied with illumination light from the primary light source 14. The primary light source 14 may be the same as employed in the first embodiment. Illumination light is directed to the incidence end face 23A through an opening of a reflector 16.

Illumination light is introduce into the guide plate 23 in the form of a beam flux having some angular extent. For the sake of explanation, the flux is represented by " illumination light L " as shown in Fig.7. The guide plate 23 may be made of the same material as that of the guide plate 13 employed in the first embodiment. Injection molding may be applied for manufacturing.

The guide plate 23 has major faces to provide an inner face 23B and an outer face 23C which is directed oppositely with the inner face 23B. The inner face 23B is facing and adjacent to the liquid crystal display panel 11. A great number of ridges 23E are arranged on the inner face 23B in order that the inner face 23B provides an emission promoting face having an emission promoting function.

According to the most important feature of the present invention, the ridges 23E are substantially nonparallel with respect to the incidence end face 23A, being inclined at a certain inclination angle α . Inclination angle α is determined according to design, falling preferably within a range from 5 to 45 degrees, in particular, from 15 to 30 degrees.

Such an inclined arrangement and the numerical ranges as above effect in the same way as in the case of the first embodiment, and accordingly, detailed description on them

is not repeated here. The ridges 23E employed in the present embodiment function also as they have an effective width that is greater than the actual width. Therefore, if such ridges as having width smaller as compared with prior arts are employed, effective width can be maintained. Ridges of small-size are hardly conspicuous, and accordingly they prevent illumination quality of the surface light source device 22 and display quality of the liquid crystal display 20 from being deteriorated.

And besides, the ridges 23E orientated obliquely reduce the possibility of Moire fringe appearance which might be caused in association with ambient periodically arranged components such as transparent electrodes. This also prevents illumination quality or display quality from being deteriorated.

The guide plate 23 (the present embodiment) differs from the guide plate 13 (the first embodiment) in the manner configuration at and around the ridges 23E, 13E. The ridges 23e and their foot portions is configurated so as to satisfy the following conditions (please see Figs. 7 and 9, in particular).

(1) Every ridges 23E has approximately the same three-dimensional shape.

(2) Each ridge 23E provides an approximately constant cross section area of " cross section parallel with the outer face 23C " overall from its base portion to top portion.

(3) The first flank face 23EA and the second flank face 23EB are steep and approximately vertical to a general plane representing the emission function face (inner face 23B). Each ridge 23E has a top face 23G at the top portion, the top face 23G extending approximately in parallel with the general plane.

(4) The first flank face 23EA is connected with the emission function face (inner face 23B) at the first foot portion 23BA while the second flank face 23EB is connected with the emission function face (inner face 23B) at the second foot portion 23BB. And the second foot portion 23BB provides a stepwise difference d with respect to the first foot portion 23BA.

This stepwise difference is formed so that thickness of the guide plate 23 is greater at the second foot portion 23BB as compared with at the first foot portion 23BA. In other words, the first flank face 23EA provides a " higher cliff " in comparison with

one provided by the second flank face 23EB. The first foot portion 23BA and the second foot portion 23BB form slopes in the present embodiment, respectively.

On lighting of the fluorescent lamp 15, illumination light L is introduced into the guide plate 23 and then propagates within the guide plate 23 so as to be getting far from the incidence end face 23A with repeated inside-reflections at the inner and outer faces 23B and 23C.

Through this process, much of illumination light L get opportunity to enter into any of the ridges 23E. In order that such opportunity increases according to distance from the incidence end face 23A, formation interval of the ridges 23E gets smaller according to the distance. This gives the surface light source device 11 a uniformized illumination output distribution.

In addition to this, inclination provided by the first and second foot portions 23BA, 23BB gets greater according to distance from the incidence end face 23A. Referring to FIGS. 8 AND 9, effects of the stepwise difference provided by the foot portions 23BA, 23BB are explained as follows.

Fig.9 shows a case where illumination light L is inside-incident to the second flank face 23EB at incidence angle that is limited as compared with that in the case shown in Fig.8. That is, the stepwise difference allows less light to be inside-incident to the second flank face 23EB at small inside-incidence angles. As a result, the liquid crystal display panel 11 is supplied with light having directivity such that less light is supplied from greatly oblique directions.

In the case of Fig.8 provided with no step difference, inside-incidence angle to the vertically steep flank face 3F has a broad distribution roughly within a range 0 degree to θ . Light illumination light L which approaches the ridge 3E at a relatively deep angle is directed to the liquid crystal display panel 11 in an roughly frontal direction after being refracted.

However, not a little component reaches the flank face 23EB at inside-incidence angle near to 0 degree as illumination light L1. Such illumination light L1 escapes easily through the flank face 3F. Although this escaping involves some refraction, escaped light is still directed greatly inclined to the frontal direction (i.e. the normal) with respect to

the liquid crystal display panel 11.

To the contrary, in the case of Fig.9, component which approaches the ridge 23E at a small inside-incidence angle as illumination light L1 is actually inside-incident to the second foot portion 23BB at a great incidence inside-incidence angle without being inside-incident to the second flank face 23EB due to step difference. Illumination light L which approaches the ridge 23E at a relatively large inside-incidence angle is directed to the frontal direction with respect to the liquid crystal display panel 11.

According the above mechanism, the case of Fig.9 provides illumination output which is much directed to the frontal direction as compared with that obtained in the case of Fig.8.

And besides, the inclination of the second foot portion 23BB as illustrated causes illumination light L1 to be modified, after undergoing inside-reflection, so that its propagation direction gets near to a direction of thickness of the guide plate 23. As a result, inside-incidence to the flank face 23EB at a relatively large inside-incidence angle tends to occur easily at the next chance of entering into any ridge, after undergoing a succeeding inside-reflection at the outer face 23C. Thus inside-reflection caused by the second foot portion 23BB scarcely impedes emission function.

In general, coming of light to the flank face 23EB requires that inside-incidence angle ϕ is greater than ϕ_0, $\phi > \phi_0$, where stepwise difference is d, interval between the flank faces 23EA and 23EB (i.e. width of the ridge 23E) W, and $\tan^{-1}(d/W) = \phi_0$. That is, illumination light having inside-incidence angle ϕ which is not greater than ϕ 0, namely if $\phi \leqq \phi_0$, is not permitted to reach thereto.

Stepwise difference d is designed based on the above conditions so that angle ϕ 0 is an appropriate small value such as 5 degrees. As to interval W, it is set at a small value so that the ridge 23E is small enough to be almost invisible. A practical range is from 5 to 50 μ m.

<3> Third Embodiment

Referring to Fig 10, illustrated is a liquid crystal display 30 according to the third embodiment. The liquid crystal display 30 comprises a surface light source device of side

light type 32 instead of the surface light source device of side light type 12 or 22. The surface light source device 32 employs a guide plate 33 instead of the guide plate 13 or ~~22.~~ 23.

Except this, the present embodiment has a skeleton structure the same as that of the aforementioned first or second embodiment. The present embodiment is structured more simply as compared with the aforementioned embodiments. Members common to the first or embodiment are referenced commonly without repeating description on them.

The surface light source device 32 is disposed at the outside (i.e. at the screen side or viewing side) of the liquid crystal display panel 11 for front-lighting of the panel. The liquid crystal display panel 11 is structured and works as described in the description of the first embodiment.

The surface light source device 32 comprises a guide plate ~~23~~ 33 and a primary light source 14. The guide plate 33 has an end face to provide an incidence end face 33A through which the guide plate 33 is supplied with illumination light from the primary light source 14. The primary light source 14 may be the same as employed in the first embodiment. Illumination light is directed to the incidence end face 33A through an opening of a reflector 16.

Illumination light is introduce into the guide plate 33 in the form of a beam flux having some angular extent. The guide plate 33 may be made of the same material as that of the guide plate 13 employed in the first or second embodiment. Injection molding may be applied for manufacturing.

The guide plate 33 has major faces to provide an inner face 33B and an outer face 33C which is directed oppositely with the inner face 33B. The inner face 33B is facing and adjacent to the liquid crystal display panel 11.

A great number of ridges 33E are arranged on the inner face 33B in order that the inner face 33B provides an emission promoting face having an emission promoting function.

According to the most important feature of the present invention, the ridges 33E are substantially nonparallel with respect to the incidence end face 33A, being inclined at

a certain inclination angle α. Inclination angle α is determined according to design, falling preferably within a range from 5 to 45 degrees, in particular, from 15 to 30 degrees.

Such an inclined arrangement and the numerical ranges as above effect in the same way as in the case of the first embodiment. The ridges 33E employed in the present embodiment function also as they have an effective width that is greater than the actual width. Therefore, if such ridges as having width smaller as compared with prior arts are employed, effective width can be maintained. Ridges of small-size are hardly conspicuous, and accordingly they prevent illumination quality of the surface light source device 32 and display quality of the liquid crystal display 30 from being deteriorated.

Besides, the ridges 33E orientated obliquely reduce the possibility of Moire fringe appearance which might be caused in association with ambient periodically arranged components such as transparent electrodes. This also prevents illumination quality or display quality from being deteriorated.

The guide plate 33 has a simplified configuration, being configurated so as to satisfy the following conditions.

(1) Every ridges 33E has approximately the same three-dimensional shape.

(2) Each ridge 33E provides an approximately constant cross section area overall from its base portion to top portion.

(3) Each pair of flank faces are steep and approximately vertical to a general plane representing the emission function face (inner face 33B). Each ridge 33E has a top face at the top portion, the top face extending approximately in parallel with the general plane.

(4) Stepwise difference as employed in the second embodiment is not adopted. In other words, the first and second foot portions are not deviated from the general plane.

Although the present structure is simplified as above, the most important and basic feature of the present invention is maintained. That is, as previously described in details, the ridges 33E function also as they have an effective width that is greater than the actual width. This allows ridges having small sizes and hardly conspicuous to be employed. As a result, the surface light source device 32 and liquid crystal display 30

can avoid reduction in illumination quality or display quality.

And beside, the ridges 33E orientated obliquely reduce the possibility of Moire fringe appearance, thereby preventing illumination quality or display quality from being deteriorated.

<4> Forth Embodiment

In the first, second and third embodiments, the emission function faces are provided by LCD-panel-side faces (inner faces). Alternatively, it may be provided by an outer face (opposite with a liquid crystal display panel). An example of this formation is illustrated in Fig.11 as the forth embodiment. Description on the present embodiment is simplified without repeating explanation.

Referring to Fig 11, a liquid crystal display 40 comprises a surface light source device of side light type 42 for front-light of a liquid crystal display panel 11. The surface light source device 42 employs a guide plate 43. The liquid crystal display panel 11 is structured and works as described previously.

The guide plate 43 may be made of the same material as that of the guide plate 13 or others. Injection molding may be applied for manufacturing. The guide plate 43 has major faces to provide an inner face and an outer face which is directed oppositely with the inner face. The inner face is facing and adjacent to the liquid crystal display panel 11.

According to a feature of the present embodiment, a great number of ridges 43E are arranged on the outer face in order that the outer face provides an emission promoting face having an emission promoting function. And according to the most important feature of the present invention, the ridges 43E are substantially nonparallel with respect to an incidence end face, being inclined at a certain inclination angle. Inclination angle falls preferably within a range from 5 to 45 degrees, in particular, from 15 to 30 degrees. Such an inclined arrangement also causes each ridge 43E to function as it has an effective width that is greater than the actual width.

Therefore, if such ridges as having width smaller as compared with prior arts are employed, effective width can be maintained. Ridges of small-size are hardly conspicuous, and accordingly they prevent illumination quality of the surface light source

device 42 and display quality of the liquid crystal display 40 from being deteriorated.

And besides, as described previously, the possibility of Moire fringe appearance is reduced. This also prevents illumination quality or display quality from being deteriorated.

Each ridge has a pair of flank faces 43EA, 43EB. In the present embodiment, the flank faces 43EA, 43EB provide a slope directed to the incidence end face and another slope opposite with the incidence end face, respectively. The flank faces 43EA and 43EB meet at a top of each ridge to provide a top line. Configuration of each ridge 43E belongs to category of " being tapered " .

On lighting of the fluorescent lamp 15, a beam flux represented by illumination light L is introduced into the guide plate 43. Thus introduced illumination light L propagates within the guide plate 43 so as to be getting far from the incidence end face with repeated inside-reflections at the inner and outer faces.

Through this process, much of illumination light L get opportunity to enter into any of the ridges 43E. As illustrated, a large part of illumination light L that has entered into a ridge 43E undergoes an inside-reflection at the second flank face (slope) 43EB, then being emitted through the inner face toward the liquid crystal display panel 11. Some of thus emitted light transmits the liquid crystal display panel 11 twice reciprocally, as described previously, then being emitted toward ambiance. As a result, out put light of the liquid crystal display panel brings image formation.

As for ambient light, it is introduced into the guide plate 43 through the outer face (any slope). Some of the ambient light transmits twice the liquid crystal display panel 11 along a reciprocal path similar to that of illumination light L, then being emitted toward ambiance. Out put light of the liquid crystal display panel RESULTANTLY brings image formation.

<5> Modifications

The above-described first through ~~third~~ fourth embodiments are not limitative to the present invention at all. Modifications such as follows fall within the scope of the present invention.

(a)In the first embodiment, each ridge is formed so that conditions of " being tapered (gradually reducing cross section) " and " inclined projection (first and second flank faces inclined opposite to an incidence end face) " are satisfied. However, each ridge may be formed so that only one of the conditions is satisfied.

It is noted that the second embodiment is out of these two conditions, employing ridges each of which satisfies conditions of " constant cross section " and " vertical projection " are satisfied.

In another employable case, each ridge is tapered (with gradually reducing cross section) and vertically projecting as a whole. However, if this case is employed, it is preferable that both of the first and second flank faces are inclined opposite to an incidence end face.

Alternatively, one of the first and second flank faces may be inclined to a general plane representing an emission function face, with the other being vertical to the general plane. For example, in a case where ridges are formed in a process after molding, manufacturing is easily performed under a condition such that " the first flank face is vertical " and " the second flank face is inclined " .

~~It is noted that the second embodiment is out of these two conditions, employing ridges each of which satisfies conditions of " constant cross section " and " vertical projection " are satisfied.~~

(b) In the second embodiment, the inner face is inclined full between ridges adjacent to each other in order to provide a stepwise difference between the first foot portion 23BA and the second flank face 23EB. Instead of this, a partial inclination may provide a stepwise difference.

(c) Although the above embodiments employ guide plates each of which has a uniform thickness, a guide plate having a wedge-like cross section may be employed instead of them.

(d) The above embodiments employ guide plates each of which is supplied with light through only one incidence end face. However this puts no limitation onto the present invention. For instance, Two side end face s opposite with each other may provide two incidence end faces.

(e) The surface light source devices in the above embodiments employ rod-like primary light sources (fluorescent lamps) to supply primary light. Alternatively employable primary light sources comprise an arrangement provided with a plurality of point-like light sources such as light emitting diodes.

(f) In each of the above embodiments, a major face opposite with an emission function face (the outer faces in the first through third embodiments; and the inner face in the forth embodiment) is a flat face. However, instead of such a flat face, a processed face my be employed. For example, anti-reflection coating may be applied. Alternatively, non-glare processing such as mat-processing may be applied.

(g) In each of the above embodiments, an incidence end face is vertical to a major face (outer face or inner face). However this puts no limitation onto the present invention. That is, an incidence end face may be inclined to a major face (outer face or inner face).

(h) In the above embodiments, the present invention is applied to surface light source devices for liquid crystal displays. However this puts no limitation onto the present invention. That is, the present invention may be broadly applied to surface light source devices of side light type for various illumination devices and displays, an to guide plates employed therein.